Dec. 19, 1939. M. J. SMITH 2,183,875

LIQUID FEED APPARATUS

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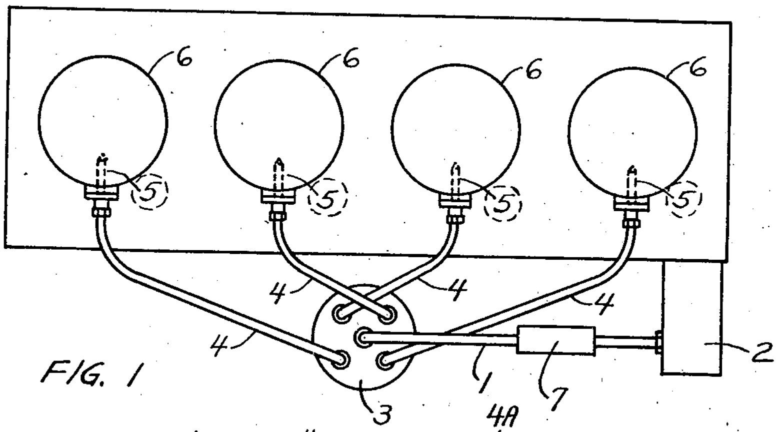

FIG. 1

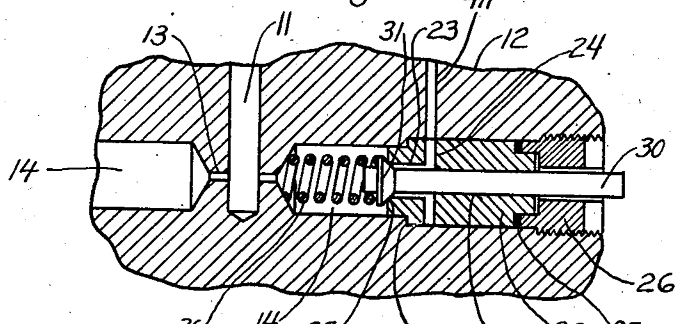

FIG. 4

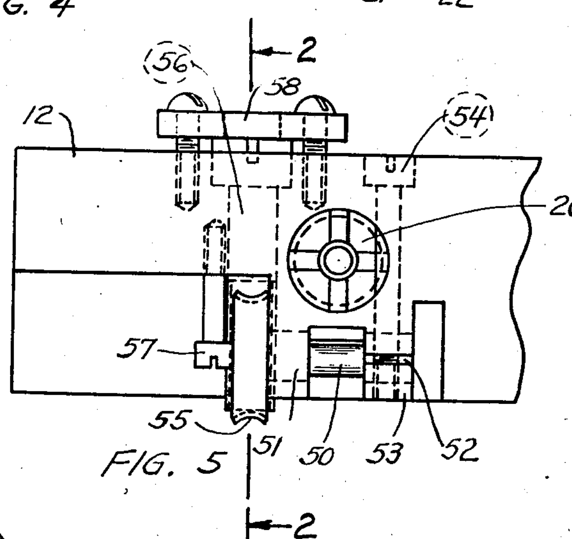

FIG. 5

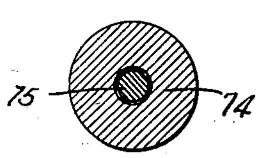

FIG. 6

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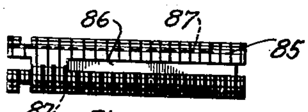


FIG. 7

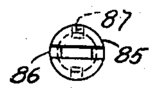


FIG. 7A

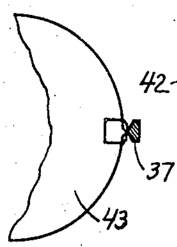


FIG. 2A

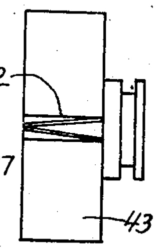
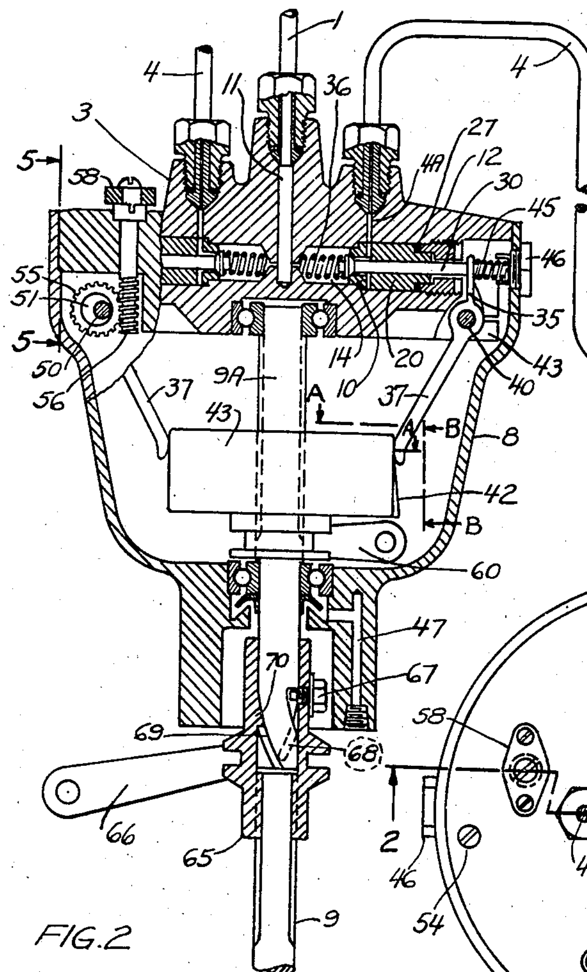


FIG. 2B



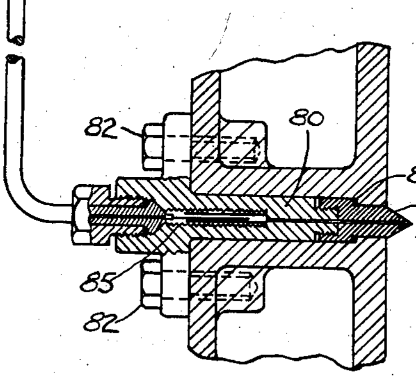


FIG. 2

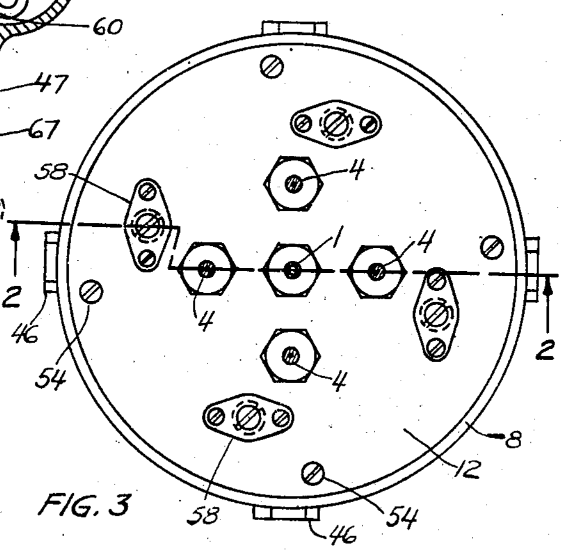
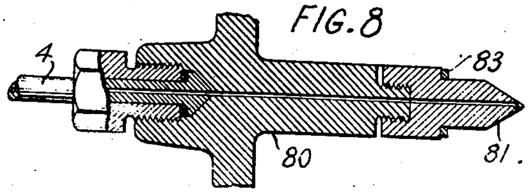


FIG. 3

FIG. 8



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UNITED STATES PATENT OFFICE

2,183,875

LIQUID FEED APPARATUS

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Application March 19, 1938, Serial No. 196,999

8 Claims. (Cl. 123—136)

This invention pertains to the field of liquid supply, and is intended for the purpose of supplying charges of liquid through a delivery duct in such a manner that a cut-off of the supply in the duct at a point removed from the delivery orifice will result in an instant cessation of delivery, without any dribbling after cut-off occurs, and this without any closing means at or immediately adjacent the delivery orifice. The invention is herein illustrated and described with respect to use in connection with internal combustion engines, particularly of the Diesel and semi-Diesel type, although uses in other fields, or for liquids other than liquid fuel, are within the scope of the invention. Besides true Diesel engines, the invention finds a usefulness for engines of the type in which gaseous fuel such as natural gas or blast furnace gas, is the primary fuel, and the charge is fired by an injection of a small quantity of liquid fuel.

The features of the invention include means for feeding small discrete quantities of liquid fuel to a point of use by successive impulses, with cessation of supply between the impulses. One inventive feature in the accomplishment of this purpose is a simple means, with no moving parts, for preventing dribbling at the delivery point between supply impulses. Other features are an arrangement of loading a valve for snap action against constant heavy pressure, and an arrangement of such valve with respect both to the duration of valve opening and the lead or lag of valve opening in the engine cycle by a single valve-actuating element.

Another aim of this invention is the provision of means to utilize a single distributor in the high pressure system to supply fuel to a plurality of points of use, with no valves beyond the distributor, thus, among other advantages, greatly simplifying the fuel supply mechanism of Diesel and similar engines, and enabling a single piece of simple self-contained apparatus, resembling the electrical distributor of a gasoline engine and connected to each cylinder only by a single tube, to be used for all the cylinders, with no moving parts at the points of delivery. This feature may be more particularized as means of liquid fuel supply under constant ultimate pressure to a distribution point, distribution from that point into capillary tubes momentarily connected at proper times to the supply means, and by such tubes to the engine cylinder, or other destination. One example of another destination is a burner, if the principles of my invention are applied to deliver fuel for heat instead of for power.

Further aims are the provision of fuel supply means for internal combustion engines as indicated above which are light and quick-acting, whereby, in conjunction with other features of the invention, it becomes possible to increase the speed of Diesel and similar engines to those on the order of gasoline engine speeds, thus opening the way to diminishing the size and weight per horse-power, giving greater operating flexibility, and other desirable results.

To the accomplishment of the foregoing and related ends, said invention, then, consists of the means hereinafter fully described and particularly pointed out in the claims.

The annexed drawings and the following description set forth in detail certain mechanism embodying the invention, such disclosed means constituting, however, but one of various mechanical forms in which the principle of the invention may be used.

In the accompanying drawings:

Fig. 1 is a general layout in diagrammatic plan view, illustrating the invention applied to a four-cylinder engine;

Fig. 2 is a vertical central section through a preferred form of distributor and a preferred form of nozzle, with their connections, with some parts in elevation, on the plane 2—2 of Fig. 3;

Fig. 2A is a plan, with part in section, on the plane A—A of Fig. 2;

Fig. 2B is an elevation on the plane B—B of Fig. 2;

Fig. 3 is a plan view of the left portion only of Fig. 2;

Fig. 4 is a valve detail from Fig. 2, on a larger scale and modified in some particulars;

Fig. 5 is an enlarged elevation of a detail taken generally as indicated by the arrows 5, 5, Fig. 2, with the housing removed, illustrating a preferred adjustable valve arm mounting;

Fig. 6 is an enlarged cross section through a modified form of capillary feed tube;

Fig. 7 is a side elevation and Fig. 7A an end view of a filter element shown in the nozzle of Fig. 2; and

Fig. 8 is an enlarged central axial section of a modified nozzle.

In the present example oil is fed from a reservoir or other supply (not shown) through a supply tube 1 by a high pressure pump 2 of a type usual for such purposes, to a distributor 3, and from the distributor through capillary feed tubes 4 to nozzles 5 in engine cylinders 6. In accordance with the usual practice, there is a surge bottle 7 on the line 1. Usual arrangements are provided to regulate pressure, such as a by-pass in the pump. The supply tube 1 is capable of withstanding the pressures generally employed in Diesel practice, on the order of thousands of pounds per square inch, but the tube walls are not unduly thick, since it is not objectionable if they stretch slightly, supplementing the effect of the surge bottle 7. All parts may be connected by high pressure fittings of conventional type.

The supply tube 1 leads into a chamber 11 in the head 12 of the distributor 3, from which valves 10 control flow into the distributor tubes 4. On account of the high pressure encountered, the distributor head 12 may preferably be formed of a single block of metal in which various bores are drilled and parts milled away from the appropriate interior and exterior parts and attachments. The entire distributor also includes a housing 8 in which the head 12 is seated and in the lower part of which an upper timer shaft 9A revolves in suitable bearings, as shown, and as described in detail hereafter.

The chamber 11, in the preferred form shown, comprises a central axial bore, preferably about the diameter of the supply tube 1, from which bore restricted orifices 13 (Figs. 2 and 4) preferably of capillary size, connect with valve chamber 14. Such orifices and valve chambers are preferably disposed with their axes on a common plane perpendicular to the axis of the chamber 11 and connecting with 11 near its bottom. The effect of the orifice 13 at certain stages of the operation, is to reduce pressure, say from 6000 pounds per square inch in chamber 11 to 5000 pounds in chamber 14, or similarly at other pressure ranges, which effect is of advantage in enabling the valves 10 to cut off sharply at all (including low) engine speeds, and keeping the valve clear when running slowly, as will be explained more fully in connection with the operating description hereafter.

Each valve 10 is seated in its bore far enough from the orifice 13 so that the capacity of chamber 14 is greater than the maximum single charge, thus preventing wire-drawing. The preferred valve construction comprises a sleeve 20, closely fitting in its bore, and preferably seating by a shoulder 21 in such bore. The sleeve 20 is longitudinally centrally apertured at 22 and 23, and also transversely apertured at 24 near the inner end, to connect with an outlet duct 4A in the distributor head 12. Inward of the transverse aperture 24, the central aperture is enlarged as at 23, and finished with a tapered seat 25 at the front end. Besides being a close fit in the horizontal bore, the sleeve 20 is held down by a hollow gland screw 26 threaded into the back part of the bore and bearing at its inner end against a packing ring 27 preferably of lead, solder or the like.

A valve stem 30 with a flaring head 31 extends through the sleeve 20 and the gland screw 26 and extends out rearwardly into contact with the upper arm 35 of a valve lever. As best shown in Fig. 4, the valve stem 30 makes a close sliding fit in the portion 22 of the aperture, but is cleared by the enlargement 23 so that when the valve is unseated, a passage is open from the chamber 14 to the duct 4A. The valve stem 30 is constantly urged outward by a compression spring 36, bearing at its opposite ends on the bottom of the chamber 14 and on the valve head 31. Inward motion is imparted to the valve 30 by the lever arm 35.

The valve lever comprises angular arms 35 and 37 pivoted on a pivot 40. The upper arm 35, already mentioned, is stiff. The dependent arm 37, much longer than 35 in the form shown, is inwardly inclined and adapted to be contacted at its lower end by a cam nose 42 on a rotor 43, which rotor is splined to the upper timer shaft 9A. A compression spring 45, weaker than the spring 36, bearing against the upper end of arm 35 and backed by a cup-pointed screw 46 in the housing 8, constantly urges the arm 35 inward, for the purpose of preventing fluttering of the valves. The shaft 9A runs on bearings in the lower side of the distributor head 12 and in the lower portion of the casing 8 respectively. An oil diversion collar and a drain 47 prevent any oil which may leak through the valve from running down the shaft 9A, and drain it out.

On account of the very small charges of fuel needed, and also on account of the very accurate measurement and termination of supply which is necessary to efficient operation, the valves 10 must open and shut with a snap under all conditions. This snap action is facilitated by making the lower valve lever arms 37 slightly resilient so that they do not open until the lower end of the arm is on the high part of the cam face 42 (Fig. 2A). Thus, the travel occasioned by the diagonal sides of 42 first causes tensing the arm 37 on the rise, so that movement is not imparted to the upper arm 35 until the lower arm is fully tensed.

A preferred form of mounting and adjustment for the valve arms is shown in Figs. 2 and 5 and comprises a pin with an eccentric intermediate portion 50 on which the valve lever is pivoted. The concentric ends 51, 52 of the pin bear in a split ear 53 below the head 12, clamped therein by a filister screw 54. A worm wheel 55 is fast to the end 51, and when rotated by a worm 56, adjusts the position of 50, as apparent from the left side of Fig. 2. The head 57 of a screw which takes into the distributor head 12 prevents the assembly 55—51—50—52 from moving endwise. The worm 56 has a slotted head, which can be clamped against movement by tightening the holding-down screws of a plate 58. The plate 58 has a central opening through which a screw driver can be inserted to turn the worm 56 when the several clamp screws are loosened. The worm is held against down travel by its own head and against up travel by the plate 58.

The rotor 43, which is splined to the upper timer shaft 9A is movable up and down on its splines by a rocking fork 60, to govern the amount of fuel supplied, according to load conditions. The fork 60 may be moved either by an automatic governor, or by the operator, as well understood in the art. The cam nose 42, as shown in Fig. 2B, is wider at bottom than top, and thus, the higher the rotor 43 is on the shaft the longer the cam holds each valve open.

To advance and retard the timing of fuel injection, or to reverse the engine, the arrangement shown at the bottom of Fig. 2 is effective, although others may be employed. The arrangement shown comprises a sleeve 65 splined above to the upper shaft 9A and below to the lower timer shaft 9, and movable axially along both shafts by a rocking fork 66 actuable by the operator. A threaded stud 67 projects through the upper part of the sleeve 65 and takes into a spiral groove 68 in the lower end of shaft 9A. Another spiral groove 69 in 9A is engaged by a key 70 on the inner surface of the sleeve 65.

Thus it is apparent that since the sleeve 65 constantly rotates with the main timer shaft 9, the vertical position of the screw 67 changes the angular position of the cam nose 42 with respect to shaft 9, thus causing an advance or retardation of the injection timing. The groove 68 is so cut that when the stud 67 is at the mid-point of the groove, injection occurs in each cylinder at upper dead center; raising the stud gives lead to the injection; lowering the stud lags the injection, and starting the engine with lag or giving it sufficient lag while running slowly will cause it to reverse, as is well understood in the art.

The distributor tubes 4 are made with very thick walls and very small ducts therethrough, referred to as capillary passages, and illustrated in Figs. 2, 4 and 8.

Obviously the capillary passage may be of other forms, for example that shown in Fig. 6, wherein the capillary space is annular in cross-section and defined between the inner wall of the tube 74 and an interior wire 75 spaced therein. It is important that the distributor tubes 4 or 74 be sufficiently thick walled to be substantially rigid, so that the pressure does not spring the walls appreciably; such springing of the walls would be followed by contraction when pressure is released and inject more fuel after the valve is cut off.

The preferred form of nozzle, shown in the right hand portion of Fig. 2, comprises a main stem 80 to which a tip 81 is screwed, the assembly being set in the engine cylinder 6 in any suitable manner, as by cap screws 82, and appropriately gasketed as at 83. The tip 81 is usually provided with a number of spray openings. The central ducts in the nozzle body 80 and tip 81 are again both of capillary size in the sense hereafter defined, that is, such that the tendency of the fuel to adhere to the walls of the tube prevents dribbling when pressure is cut off.

A modified nozzle, without a filter, is shown in Fig. 8. This nozzle may be used with a form of filter such as shown in side elevation in Fig. 2 and also shown in enlargement in Figs. 7 and 7A. Such filter comprises a screw threaded stud 85 in a correspondingly threaded bore in the rear part of the nozzle body 80. Longitudinal slots 86 and 87 extend from one end to near the other end of the outer surface of the stud, and are cross-connected at the stud ends, so that all the slots overlap to some extent in length but are separated by a considerable portion of the circumference. Oil feed is between the male and female threads.

The fuel passages from valves to and through nozzles are of such size with respect to the physical properties of the fuel used, that the result attained by the invention is that the surface friction of the fuel on the walls of the duct, and the surface tension at the discharge orifice, offer sufficient resistance to prevent any flow except when there is pressure. For example, with a larger size tube, the liquid in the tube would continue to dribble out of the nozzle after the pressure was cut off, thus completely destroying any accuracy of feed. Another way of stating the same thing is that I apply the term "capillary" to a tube of such characteristics that when applied pressure (as from the pump 7) is cut off, the pressure on the liquid in the tube due to forces other than applied pressure (e. g., gravity, expanding tendency in the liquid, any trade of surge effect, and other influences tending to make the tube empty itself) is less than the surface tension at the discharge orifice. It has been customary in Diesel engine practice to apply pressure very close to the point of injection to avoid this difficulty, but in my invention the use of a substantially capillary passage makes such a provision unnecessary, because no oil whatever passes out of the nozzle opening after the valve head 31 seats at 25. The word "capillary" as used in the specification and the claims appended thereto is to be interpreted in this sense.

The action of the mechanism is as follows:

Pressure being applied by the pump 2, fuel oil under high pressure is supplied to the central chamber 11, and, through the capillary connections 13, to the side chambers 14. Rotation of the cam disk 43 rocks the valve levers and so opens the valves 10 in sequence. As each valve opens, the oil under pressure travels out through the passages 3, 4A and 4 to the discharge orifice at the nozzle tip.

It is important to have the valve action quick, and the quickness of this action, especially when cranking over to start or when running at low speeds, is assisted by the following effect: When the valve starts to lift, the first very slight relief of pressure in the side chamber 14 permits quick completion of the opening under the spring tension in the valve lever arms 37, so that a snap opening results. By reason of the greatly reduced passage 13, the pressure in the central chamber does not immediately replace the drop caused in 14 by the beginning of the opening, so that the valve opening is opposed by less than full line pressure after the opening starts.

Correspondingly, when closure begins the valve starts shut under the action of the return springs, but as soon as the area between the seat and the head becomes smaller than the inlet duct, the pressure in 14 builds up and snaps the valve shut.

As previously noted, the passage from the distributor to the nozzle is of capillary size or capacity. For this reason liquid fuel movement takes place through the passages beyond the distributor as soon as opening of the valve admits pressure to such passages, but the flow ceases instantly when pressure is cut off, because, by virtue of the substantially capillary sizes, the viscosity of the liquid, surface adhesion of the liquid to the walls of the passage, and surface tension across the final discharge orifices, are effective to stop any further flow, there not being enough body of liquid in the passage to overcome resistance and to dribble at the nozzle.

Other modes of applying the principle of my invention may be employed instead of the one explained, change being made as regards the means and steps herein disclosed, provided those stated by any of the following claims or the equivalent of such stated means be employed. In the claims the word "high" is used to mean pressures on the order of those used for injection of fuel into Diesel engines, without, however, limiting the claims to this field unless they are so limited by other expressions.

I therefore particularly point out and distinctly claim as my invention:

1. As a means of supplying discrete charges of liquid of definite duration to a point of delivery, a source of supply under pressure, a valve, and a capillary passageway from said valve to the point of delivery, said passageway being open from said valve to the discharge end.

2. A fuel injecting device for internal combustion engines comprising in combination a high

pressure liquid fuel supply, a distributor fed by said supply, a plurality of quick-acting valves in said distributor, and open-mouthed capillary passages from said valves to the engine combustion chambers, said valves controlling supply of fuel to said passages.

3. A supply system for injecting liquid fuel into internal combustion engines comprising a passage for liquid fuel from a source of supply to an engine cylinder, means for moving liquid fuel through such passage under high pressure, a valve controlling the entrance to said passage, means for operating said valve, said passage being of capillary size and constantly open between said valve and the point of injection.

4. In a device of the class described, a source of liquid supply under constant pressure to a distribution point, valve means at such distribution point, and distributing channels from said point to open delivery orifices, said channels being of sufficiently small cross-sectional size as to retain liquid therein from said valve means to said orifices when pressure is cut off at said valve means.

5. A pressure system for handling liquids in separate charges, comprising a source of supply under pressure, a feed passage, a valve controlling the entrance to said passage, said passage being constantly open beyond said valve, said passage being of capillary size between said valve and the point of delivery.

6. In an apparatus for injecting liquid fuel into an engine cylinder, a supply line, pressure means for feeding liquid fuel into said supply line, a cut-off means on said supply line, operating elements for said cut-off means synchronized with the piston movements of the engine, a capillary passage from said cut-off means into the engine cylinder, and a nozzle forming part of said passage and entering said engine cylinder, said passage and said nozzle being constantly open beyond said cut-off means.

7. A distributor for liquid fuel at high pressures, comprising in combination a primary supply chamber, a secondary chamber, a passage of small diameter connecting said chambers, said primary chamber being continuously connected to a source of constant high pressure, a poppet valve controlling discharge from said secondary chamber, and a capillary passage of larger diameter than said first-named passage from said valve to a point of delivery, said valve being the only valve connected with said second named passage.

8. As a means of supplying discrete charges of liquid of definite duration to a point of delivery, a source of supply under pressure, a valve, and a capillary tube from said valve to the point of delivery, said tube having walls substantially nonstretchable under the pressures to be used therein, said tube being open from said valve to the discharge end.

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